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Using Energy Interventions to Drive Down Energy Consumption: An Occupant Behaviour Case Study

Dr Paul Hampton
School of Architecture and Built Environment, University of Wolverhampton, UK
P.Hampton@wlv.ac.uk

Pablo A. Perez
School of Architecture and Built Environment, University of Wolverhampton, UK
P.A.PerezJimenez@wlv.ac.uk

Robert Stuart
School of Architecture and Built Environment, University of Wolverhampton, UK
Robert.Stuart@wlv.ac.uk

Neil Young
School of Architecture and Built Environment, University of Wolverhampton, UK
Neil.Young@wlv.ac.uk

Abstract

The reduction of carbon emissions to the atmosphere is widely accepted as a measure to mitigate one of the greatest challenges facing the world, global warming. One of the major contributors identified as contributing to this phenomenon is the domestic market. The domestic buildings are considered to play a significant role as they represent 30 percent of the UK's energy use and produce 15 percent of the carbon dioxide emissions. As part of a UK intervention, studies have suggested behavioural change among housing occupants could be one of the key measures in the drive to reduce the use of energy. This is also expected to decrease the levels of fuel poverty. The aim of this research was to evaluate the effectiveness of the energy advice programme delivered by a UK housing association: Wolverhampton Homes, to tenants interested in energy saving and thereby reducing their fuel expenditure. The methodology incorporated a series of qualitative semi-structured interviews to three different householder groups: a control non-assisted group, a regularly assisted group and the last group supported by energy saving monitoring devices. It was determined that occupants receiving assistance are more likely to realign their behaviour and reduce energy usage within their property if presented with clear a non-technical guidance. Furthermore, the use of monitoring devices as an easy way to visualise energy consumption aided the programme in enhancing the engagement of the tenants in energy saving behaviour patterns. The findings confirm a positive approach that UK local authorities and Housing Associations can adopt in order to reduce energy consumption through influencing occupants behavioural change, promoting energy saving within domestic properties and reducing fuel expenditure.

Keywords:

Energy consumption, Occupant Intervention, Occupant Behaviour

1. Introduction

The actual problem of climate change has been highly active and widely discussed on the global agenda. The main objective has been to reduce the emissions of greenhouse gases produced by residences, industries and transport. As one of the most abundant greenhouse gases, carbon dioxide (CO_2) is listed as one of the leading causes of global warming. One of the major contributors to this is domestic buildings. In the UK, the domestic sector accounts for 15 percent of the UK's CO_2 emissions (*DECC, 2016*), has been causing concern to all associated stakeholders. Alongside the environmental issues, fuel poverty is now affecting more than 2 million households *(Wright and Nash, 2014)* caused in-part by the high energy consumption combined with relatively high fuel cost.

The UK government is committed, by law, (Climate Change Act 2008) to an 80 percent reduction in carbon emissions from 1990 levels, by 2050 *(Leichman et al, 2012).* This has resulted in the introduction of new regulations and energy saving initiatives. The reduced impact of the "Green Deal" government initiative and its intention to retrofit the existing houses led to the emergence of more economical methods to reduce the use of energy and the emission of CO_2.The initiatives also investigated how fuel costs may be reduced by increasing occupant understandings of how to use new technologies operate. This acknowledges how levels of energy use in domestic homes are mainly influenced by the demand for heating, the comfort expectations of the residents, and increased use of appliances. *(Yohanis, 2012).*

As people spend up to 90 percent of time indoors *(Halliday, 2009)*, research have identified that behavioural change in the regular activities can have a significant impact on domestic energy use. Wood and Newborough (2003) suggested the reduction of energy consumption, by the use of more efficient appliances, minimising the use of heating through the promotion of energy-conscious behaviour.

However, *(Wright and Nash, 2014)* suggest that the majority of UK social housing residents have reduced levels of understanding surrounding energy consumption and associated fuel costs. As a consequence this lack of awareness, suggests fuel bills increase, forcing residents to manage their energy use by under heating their homes and leaving them exposed to health risks.

It has been reported that individuals tend to adopt opinions, judgements and behaviours of others in their social circles *(CO, 2011)*. With this in mind, social landlords have been influenced to implement interventions to improve levels of awareness of energy consumption among the housing occupants and therefore reduce the levels of fuel poverty. These interventions tend to consist of a regular visit to homes, providing informed materials to further educate residents about the impact of behaviour and use of appliances on energy consumption in their home. The interventions provide advice on how to undertake household tasks with improved energy efficiency. (e.g. using cold water in washing machines, reducing the frequency of household chores, avoiding the increased use of tumble dryers, etc.). For this case study, the effectiveness of increased knowledge transfer is evaluated by measuring the day-to-day energy usage and the impact of the behaviour of social housing residents located in the West Midlands, UK.

2. Methodology

The aim of this study was to monitor and measure the impact of the Home Energy Visit (HEV) programme developed and implemented by a West Midlands social housing landlord: Wolverhampton Homes. In particular, the case study evaluated the influence and effectiveness by the introduction of clear visual energy and room comfort display screens. The methodology incorporated a series of qualitative semi-structured questionnaire along with periodic readings of the energy use in the property for six weeks during the heating season (October-November 2015). The questionnaire was designed to gather general information such as the number of occupants, the use of domestic appliances and their self-perception of health and wellbeing. The conversation with participants included the rationale and context for the

investigation. How the findings may assist in providing participants with more informed knowledge surrounding energy usage and how the recommendations will be disseminated to participants and associated stakeholder.

To develop the research, twenty-four homes were self-selected and divided strategically into three groups:

- Control Group:

These eight homes did not receive assistance from the social landlord.

- Standard Home Energy Visit (HEV):

These eight homes had received energy advice and a regular energy visit by an agent, who provided the occupants with guidance on how to reduce the use of energy in their home tasks.

- Eight Homes with HEV enhanced by two additional displays (HEVE):

The final eight homes had also received energy advice and were supported by similar energy visits as the HEV group. Additionally, two display sensor screens were installed, allowing the occupants to monitor their "real time" electrical energy consumption and room comfort (humidity and temperature)

This set of landlords selected households included a range of house-types including semi-detached and terraced houses of various ages and various occupancy levels. These houses tended to have, on average, three bedrooms *(Table 1)*. The case study participants had already expressed an interest in reducing energy consumption in their homes, but were unaware of how they may affect change and reduce energy consumption through their behaviour.

Table 1: Average Number of Occupants and Bedrooms per Group

	Control Group	HEV	HEVE
Average Occupant numbers	4	3	4
Average Bedroom numbers	3	3	3

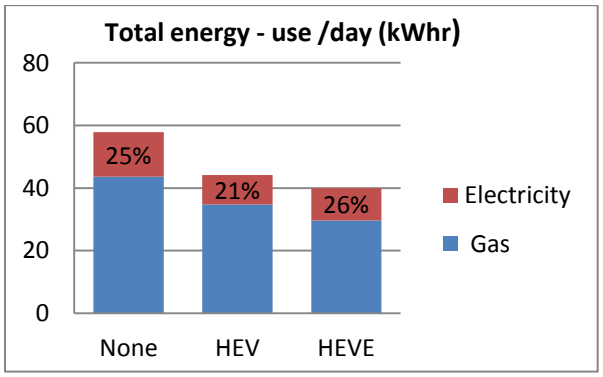
After the data was collected, descriptive statistics was applied as they play a significant role in summarising and understanding data.

3. Energy Consumption

All electrical and gas data was converted to kWh. The consumption of electrical energy was strongly affected by the number of occupants. Electrical use per day per occupant was used in comparisons below. Gas was supplied to all homes and used solely by the boilers to supply space heating and hot water. Between 75 and 85 percent (*DECC, 2014*) of boiler output is used for space heating. The amount of space heating is strongly influenced by the heating envelope of the building. Gas use per day per cold area (area exposed to unheated or outside spaces) per m^2 measured against, wall, floor and ceiling areas, was used in comparisons below.

The methodology used for this case study to provide meaningful comparisons included:
Electricity consumption measured through appliances which is mainly influenced by the number of occupants per household. Gas consumption was measured as a unit of kilowatt hours measured against the cold surface area of external wall and elements such as roof.

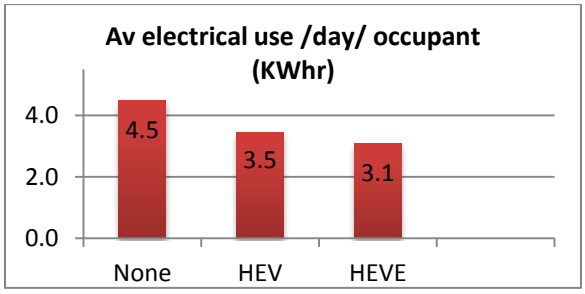
In respect of gas and electricity energy consumption, a daily average was calculated from the weekly readings in the household and is used to represent the total energy spent in each group (*Graph 1*):



Graph 1: Total Energy Use

The control group represented the highest energy consumption with 58 kWhr energy use per day of which 25 percent represented the use of electricity. The group with regular energy visits (HEV) consumed 44 kWhr per day of total energy, showing a significant 24 percent less consumption than the control group. Whereas, the group with the additional sensors screens (HEVE) had adjusted energy consumption and/or behaviour, consuming 40 kWhr per day for a 31 percent variation, compared against the control group. This acknowledges that the use of electricity depends on the frequency of use of electrical home appliances by the occupants, (washing machines, tumble dryers, refrigerators, freezers, dishwashers, microwaves, etc.).

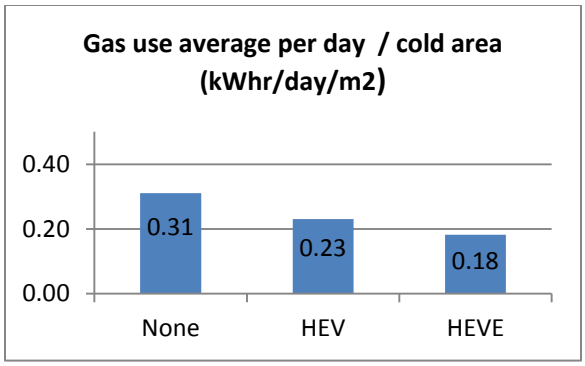
The electricity consumption also tends to be higher in more populated homes, therefore, in order to provide a comparative set of results the use of electricity is measured by occupant (*Graph 2*):



Graph 2: Average Electrical Use per Day per Occupant

Not showing a different outcome, the HEV group presents a 23 percent reduction in daily consumption in electrical use per occupant (1 kWhr per day). Likewise, the group with electricity display sensors (HEVE) had a higher 31 percent reduction (3.1 kWhr per day) when compared to the control group (4.5 kWhr per day).

When the daily use of gas is divided by the area of the walls exposed to the outside cold area, (ca), the HEVE group reduced gas consumption (0.18 kWhr/d/m2), with a 42 percent less gas consumption than the control group (0.31 kWhr/d/m2). In like manner, the group which received guidance for energy saving (HEV) had 26 percent less usage of gas (*Graph 3*).



Graph 3: Average Gas Use per Day per m^2 of Cold Area

4. Domestic Appliances

Regional evidence-based research undertaken by West Midland housing associations, suggest that their occupants have little or no knowledge of how to effectively use their installed devices.

Over the last three decades, there has been an increase in the use of domestic appliances within households *(Yohanis, 2012)*. As part of the questionnaire, the tenants reported the frequency of use of particular appliances *(Table 2)*:

Table 2: Average Frequency of Use of Domestic Appliances: Scale 1 Less Frequent-5 Very Frequent

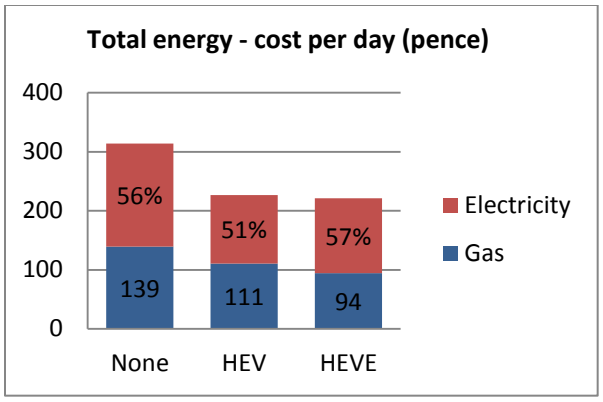
	Control	HEV	HEVE
Dryer	3	3	4
Washing machine	3	3	4
Dish washer	1	2	1
Shower/Bath	4	4	3
Heating Controls	2	3	3
Kettle	4	3	3
Cooker/Oven	4	3	3

The responses from the measure of the frequency of use of domestic appliances investigation between different groups imply a similarity between usage of appliances and potential similarities in the behaviour of occupants. In the light of this, the variance in the energy consumption between the groups is linked to how efficient the appliances are being used and possible adjustments to behaviour patterns.

5. Economic Impact

Besides the impact of the use of energy in the emission of greenhouse gases, there is a high fuel cost which affects the economy of households and, indirectly, the social landlords. Moore *(2012)* reported that the cost of energy represents between 13-14 percent of households income and therefore has influence in the rising fuel poverty across the UK.

On average, gas costs 3.19p/kWhr whilst electricity is supplied at 12.3p/kWhr. With this in mind, it is important to mention that the average energy cost per day shows a significant variance within the studied groups (*Graph 4*):



Graph 4: Average Total Energy Cost per Day

The control group pays on average £3.16 per day for the use of energy. Meanwhile, the groups with more conscious energy behaviour pay an average of £2.25.

As shown above *(Graph 4)*, the use of electricity accounts for more than 50 percent of the total cost of energy in dwellings. This means those small savings in electricity usage translate into significant financial savings. In terms of total savings, the 31 percent variance of the HEVE group represents an average saving of £30 for the households.

6. Conclusions

The domestic sector accounts for a third of the energy consumed in the UK and produces 15 percent of the carbon emissions. The consumption depends on two main factors: the energy efficiency of the buildings and the energy behaviour of households.

The significant capital investment required to retrofit existing homes to improve energy efficiency and reduce energy usage costs has encouraged householders to consider alternative solutions.

Occupants are reluctant to invest in long-term acquisitions and prefer short-term solutions. Therefore, the change of behavioural aspects might lead to an economical measure to achieve short-term objectives. As the energy consumption in domestic houses can be reduced by 10-30 percent. What this case study has evidenced is that by increasing occupant's knowledge and understanding of energy usage encourages modifying behaviour leading to improved energy savings.

Whilst acknowledging that the sample of the study is relatively small, the results suggests how the provision of feedback and guidance can help people to reduce the use of energy. The role of the housing associations of helping residents by implementing energy interventions can lead to an estimated 24 percent reduction in the use of household energy. Furthermore, the use of energy can potentially be further reduced if visual display screens are installed within the properties. This includes the temperature/humidity and electricity consumption displays used in this case study,

To further validate these case study findings, it is suggested that a broader in-depth study is undertaken and different house types and occupants are monitored. However, initial findings from this case study suggest that where energy interventions are readily accessible to householders, this can lead to significant energy savings.

7. References

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